Remarks

Claims 1-11 are pending in the above captioned application. Claims 1-11 stand rejected. Claims 1-11 have been amended to return the claims to the original un-amended form in which the claims were originally filed in the above captioned application, with amendment to correct an obvious typographical error in claim 1. Applicant submits that the Examiner's combination of United States Patent No. 5,729,565, entitled DISCHARGE UNIT AND ELECTRODE FOR A PULSED DISCHARGE LASER, issued to Meller et al. on March 17, 1998 based on an application 827,973, filed on November 7, 1996 ("Meller") and United states Patent No. 4,742,527, entitled LASER HAVING BRAZED ANODE, issued to Weidemann et al. on May 3, 1988, based on an application Ser. No. 735,560, filed on May 17, 1985 ("Weidemann") is improper in that Weidemann is non-analogous art and, further, the combination does not result in the invention as claimed.

As noted in the Specification of the above captioned application:

> The principal components of a prior art KrF excimer laser chambers are shown in FIG. 1. This chamber is a part of a laser system used as a light source for integrated circuit lithography. These components include a chamber housing 2. The housing contains two electrodes cathode 84 and anode 83 each about 55 cm long and spaced apart by about 20 mm, a blower 4 for circulating a laser gas between the electrodes at velocities fast enough to clear (from a discharge region between the two electrodes) debris from one pulse prior to the next succeeding pulse at a pulse repetition rate in the range of 1000 Hz or greater. (Gas velocities of about 10 m/s for each 1000 Hz pulse rate is typical.) The chamber includes a water cooled finned heat exchanger 6 for removing heat added to the laser gas by the fan and by electric discharges between the electrodes. Blower 4 is typically a squirrel cage type tangential fan providing high gas flow but at relatively low differential pressure. The chamber may also include baffles 60 and 64 and vanes 66 and 68 for improving reducing discharge caused acoustic effects and the aerodynamic geometry of the chamber. The laser gas is comprised of a mixture of about 0.1 percent fluorine, about 1.0 percent krypton and the rest neon. Each pulse is produced by applying a very high voltage potential across the electrodes

with a pulse power supply which causes a discharge between the electrodes lasting about 30 nanoseconds to produce a gain region about 20 mm high, 3 mm wide and 525 mm long. (Two capacitors of a peaking capacitor bank are shown at 62.) The discharge deposits about 2.5 J of energy into the gain region. As shown in FIG. 2, lasing is produced in a resonant cavity, defined by an output coupler 20 and a grating based line narrowing unit (called a line narrowing package or LNP, shown disproportionately large) 22 comprising a three prism beam expander, a tuning mirror and a grating disposed in a Littrow configuration. The energy of the output pulse 3 in this prior art KrF lithography laser is typically about 10 mJ.

FIG. 3 shows an enlarged view of cathode 84 and anode 83. Each is about 3 cm wide but the discharge region 85 is only about 3 to 4 mm wide. The direction of gas flow is shown at 86 and a gas flow of 20 m/s is indicated. The cathode and anode are typically brass. The cathode is typically slidingly mounted on an insulator 84a and the anode is typically mounted on a metal support 83A.

These KrF lithography lasers typically operate in bursts of pulses at pulse rates of about 1000 to 2000 Hz. Each burst consists of a number of pulses, for example, about 80 pulses, one burst illuminating a single die section on a wafer with the bursts separated by down times of a fraction of a second while the lithography machine shifts the illumination between die sections. There is another down time of a few seconds when a new wafer is loaded. Therefore, in production, for example, a 2000 Hz, KrF excimer laser may operate at a duty factor of about 30 percent. The operation is 24 hours per day, seven days per week, 52 weeks per year. A laser operating at 2000 Hz "around the clock" at a 30 percent duty factor will accumulate more than 1.5 billion pulses per month. Any disruption of production can be extremely expensive. For these reasons, prior art excimer lasers designed for the lithography industry are modular so that maintenance down time is minimized.

Maintaining high quality of the laser beam produced by these lasers is very important because the lithography systems in which these laser light sources are used are currently required to produce integrated circuits with features smaller than 0.25 microns and feature sizes get smaller each year. Laser beam

specifications limit the variation in individual pulse energy, the variation of the integrated energy of series of pulses, the variation of the laser wavelength and the magnitude of the bandwidth of the laser beam.

Typical operation of electric discharge laser chambers such as that depicted in FIG. 1 causes electrode erosion. Erosion of these electrodes affects the shape of the discharge which in turn affects the quality of the output beam as well as the laser efficiency. Typically, anode erosion in these excimer lasers is two to three times as severe as cathode erosion.

Electrode erosion is the result of a complex combination of physical phenomena including fluorine chemical attack and ion induced sputter. Use of alloys of copper for electrodes for gas discharge lasers is well known. For example, a common electrode material is a brass known as C36000 which is comprised of 61.5% copper, 35.5% zinc and 3% lead. It is known to anneal brass parts before they have been machined to make the parts less brittle.

The specification of the above captioned application goes on to state:

The present invention provides an excimer laser with a laser chamber containing a circulating laser gas containing fluorine and long-life, annealed, copper alloy electrodes. Electrode lifetime is increased by annealing them after the electrodes are machined. This annealing relieves the surface stress caused by the machining operation and reduces the exposed metallic grain boundary length per unit area on the surface of the electrodes, which provides substantial reduction in erosion caused by fluorine chemical attack. Annealing after machining also reduces the stress throughout the bulk of the electrode material. In preferred embodiments the anode is a copper-aluminum alloy and the cathode is a copper-zinc alloy.

In stark contrast to the above described invention and the environment in which it is utilized, Weidemann describes:

An ion laser is described having an anode construction which has no special configuration specifically designed to accommodate differential thermal expansion between it and a ceramic tube. The anode includes a radially thick first portion for good thermal conductivity and a thin-walled sleeve integral therewith

extending beyond the tube to provide an exterior surface for electrical connection. (Abstract).

Weidemann also mentions:

The configuration of the electrode and of the tube at the electrode location assures that a good direct adherence is achievable with brazing. In this connection, expansion miss-match is accommodated by annealing of the metal, preferably copper, and by the geometrical configuration of the structure. Moreover, this configuration and the construction of the invention enables such direct adherence without the metal of the tube being configured to flex to accommodate differential thermal expansion. (Col. 1, line 68 – Col. 2, line 10).

Weidemann further states:

The metal of the electrode preferably is annealed to minimize internal stresses. If the electrode is of copper as is preferred, it automatically will be annealed when the construction is raised to the brazing temperature. (Col. 2, lines 29-32)

Weidemann describes in great detail the construction and fabrication of "the preferred embodiment of a gas ion laser incorporating the present invention" (Col. 3, lines 34-35) as follows:

As another salient feature of the invention, the electrode is provided with an electrically conductive surface at both the interior of the tube and at its exterior, and a conductive electrical connection is provided to the exterior surface. The result is that an electrical potential can be provided to the interior of the containment volume without penetration for leads for the electrode. Again, the configuration of the electrode enhances such construction.

The electrode preferably is an anode that includes a radially thick first portion having a radially thin-walled sleeve extending outwardly beyond the ceramic tube portion mentioned above providing the surface which is exposed to the exterior of the tube to which the conductive electrical connection is made. Most desirably, exterior connection is made by a conductor in the form of a ring or clamp circumscribing and mating with the exteriorly exposed sleeve surface. Supporting structure is provided within the interior of the anode to prevent collapse of the thin-walled sleeve under pressure of the connector clamp. Such

support most simply is provided as the ceramic end tubing of a window structure located at the end of the tube having the anode. The exterior surface of the ceramic end tubing of the window structure mates with the interior surface of the sleeve and thereby provides support.

The invention further includes a method of manufacturing the laser tube to enhance the electrode securance. It includes providing the ceramic tube having a cylindrical interior surface at one end, providing an electrode having a cylindrical outer surface whose axial dimension is greater than its radial dimension and thereafter directly adhering the two surfaces together. As mentioned previously, such adherence is preferably obtained by brazing and a greater axial extent of the exterior surface of the electrode than the radial dimension of such electrode, is brazed to provide such direct adherence. (Col. 2, line 51 – Col. 3, line 20)

Still further, Weidemann explains:

As a salient feature of the instant invention, it includes an anode electrode structure which has a configuration eliminating many of the limitations of past designs. The anode itself is of a metal to be a good electrical conductor and yet in keeping with the invention it is secured to the ceramic portion of the tube in a manner which assures good vacuum sealing. With reference to FIG. 2, the anode assembly 17 includes a ceramic cylinder or end cap 42 which is adhered directly to the ceramic bore 16. The cylinder 42 is also preferably of BeO and it will be recognized that a good vacuum tight mechanical securance to the bore 16 is achievable, particularly since there is essentially no different radial thermal expansion of the tube 16 end and cylinder 42 over to the temperature range to which the securance joint is subjected during normal usage of the laser.

The anode itself is cylindrical and is generally referred to by the reference numeral 43. It is made of OFHC copper for high electrical and thermal conductivity and good vacuum compatibility. In accordance with the invention, it is directly adhered to the ceramic of the tube (to the ceramic cylinder 42) without special steps being taken to accommodate differential thermal expansion between such electrode and the ceramic. In this connection, it will be recognized that there is significant differential thermal expansion between a metal and a ceramic. The

securance is achieved with a vacuum-tight seal over a large surface area. To this end, the electrode 43 has an outer cylindrical surface 44 whose axial dimension is greater than its radial dimension a portion of which mates with and is brazed to the interior surface 46 of the ceramic cylinder 42. As an example, in one embodiment the anode itself had a 0.373 inch diameter and a length of 1.38 inches. Approximately 70% of the exterior surface of the anode itself was adhered by brazing to the interior surface of the cap 43. The surfaces 44 and 46 are plated respectively with silver and molybdenum manganese plus nickel prior to the anode being assembled within the cylinder 42. The diameter of the anode is slightly less than the diameter of the interior surface 46 of such cylinder. The result is that these parts easily can be mechanically assembled together. They are then raised to the brazing temperature. The coefficient of thermal expansion of OFHC copper, the preferred material for anode 43, is 20.1.times.10.sup.-6 in/in/.degree. C. whereas the coefficient of thermal expansion of BeO, the preferred material for cylinder 42, is 8.5.times.10.sup.-6 in/in/.degree. C. This fact is used in the instant invention to enhance the adherence of the anode to the tube. That is, upon these parts being raised to the brazing temperature, the thermal expansion of the metal anode 43 in the radial dimension will be greater than the thermal expansion of the cylinder. There therefore is a tight mechanical fit during brazing. This assures that a thin braze which provides a good thermal path between the anode and cylinder, is achieved. The silver plated copper forms a copper/silver utectic which flows at 800.degree. C. and forms the necessary braze alloy to make the joint. Due to the extreme ductility of OFHC copper at the braze temperature, the tensile forces on the ceramic do not break it.

It will be recognized that when the assembly is returned to ambient temperature, the radial dimension of the anode 43 will tend to shrink to a greater extent than the radial dimension of the interior surface of the cylinder 42. The result is that some stress will be built up between the parts 42 and 43. However, this stress is spread over a significant surface area in view of the fact that the braze covers a relatively large surface area, and the joint and structures can accommodate the same.

The configuration of the electrode relative to the cylinder 42 also aids in achieving the desired adherence. It has a radially thick first portion 47 which includes an axial passageway for the passage there through of optical radiation, and a radially thin second portion which, in effect, defines a thin-walled sleeve 48. The surface 44 of the anode which is adhered to the surface 46 of the end cap is provided as illustrated by both the portions 47 and 48. As mentioned previously, the dimensional change in a metal due to thermal variations is significantly greater than that of a ceramic. The coefficient of thermal expansion of a material is a measure of such change.

The electrode configuration is selected to enhance laser operation. That is, the portion of the same at which significant thermal energy is generated, i.e., its first portion, is radially thick for good thermal conductivity. The free end of the thick-walled portion is conical in shape to increase its surface area for distribution of the discharge. The thin-walled sleeve 48 integral therewith allows desired electrical conductivity, but minimizes thermal conductivity from the discharge because of its thinness. In other words, the configuration of the anode provides good thermal conductivity in the radial direction but not in the axial direction. The fact that the thin-walled sleeve is an integral part of the anode, i.e., the anode is a one-piece construction, assures good electrical conductivity. (Col. 4, line 51 – Col. 6, line 12)

It is also well known that gas ion lasers are totally unsuited for the types of high pulse repetition rates according to the above described environment of the electrodes according to the present invention. Indeed, they are or were used in an on-off mode of relatively continuous operation, compared to pulsed operation at pulse widths measured in nanoseconds, generally require a preheating time to heat at least one of the electrodes before creating the discharge between the electrodes. They are not subject to the complications of utilizing a laser gas comprising fluorine, and do not utilize an elongated electrode with a small portion thereof comprising a discharge region. For more details on ion gas discharge lasers see http://repairfaq.cis.upenn.edu/sam/laseraps.htm#apsbcs1 and http://www.rli.com/resources/argon.asp copies of the content of which are included along with this response.

In short gas ion lasers are totally foreign to excimer gas discharge lasers of the type disclosed and claimed in the present application such that, even if Weidemann taught or suggested machining and then annealing an electrode for the purposes outlined above in the quoted portion of the specification of the above captioned application, which Weidemann does not teach or suggest, persons of skill in the art would not look to electrodes utilized in ion gas laser tubes of the type described in Weidemann for solutions to totally foreign and distinct problems presented by excimer gas discharge lasers of the type disclosed and claimed in the present application.

In any event, Weidemann does not disclose an electrode that is machined and then annealed. In the noted portions of Weidemann cited above, Weidemann teaches, at best, that the construction taught by Weidemann is facilitated – the cracking of the surrounding ceramic cylinder is made less likely - if one uses an annealed metal, or better yet, the preferred pure copper anode, such that at brazing temperature the copper becomes ductile enough that the ceramic will not crack. The Examiner's suggestion that Weidemann's silence on whether to anneal first and then machine or vice-versa means that Weidemann teaches doing it either way is not supported in fact or law. Indeed, Weidemann does not even say that the shape of the anode piece is formed by machining at all. I could just as well be cast or molded.

In regard to claims 2-11 they depend from allowable claim 1 and should be allowed for that reason. *In re Fine*, 837 F.2d 1071, 5 U.S.P.Q.2d 1596 (Fed. Cir. 1988).

Further, respecting claims 2-11[1] the Examiner has rejected the claims under 35 U.S.C. §103 (a) as unpatentable over Meller in view of Weidemann as applied to claim 1 and in addition United States Patent No. 4,860,300, entitled ELECTRODE FOR PULSED LASERS, issued to Baumler et al. on August 22, 1989, based upon an application Ser. No. 303,083, filed on January 27, 1989 ("Baumler"). Baumler discloses an electrode for a gas discharge laser that contains copper, aluminum, nickel and iron. What Baumler does not disclose is the electrode in question is the anode. Applicants have discovered that long life characteristics for such gas discharge electrodes in the excimer gas discharge laser environment utilizing a laser gas comprising fluorine not

[1] The Examiner appears to be only referring to claims 2-4 here, since the Examiner only references the disclosure of Baumler relating to copper, aluminum, iron and nickel, which are the elements recited in claims 2-4.

only depends upon the material from which the particular electrode is made, but that from which its opposing electrode is made. Baumler says nothing about selection of only one electrode, the anode as claimed, as opposed to using the same electrode composition for both anode and cathode.

The Examiner has taken the position that "[d]etermining the exact composition of the elements involves routine skill in the art." The Examiner has not cited specific authority for this pronouncement, but appears to be referring to cases like *In re* Aller, 220 F.2d 454, 456, 105 U.S.P.Q. 233, 235 (C.C.P.A. 1955) ("[W]here the general conditions of a claim are disclosed in the prior art, it is not inventive to discover the optimum or workable ranges by routine experimentation."). However, the statement of the law in *Aller* has been limited to optimizations of known result determinative variables. See, Sheldon, J. "Manual of Patent Examining Procedure 2144 Sources of Rationale Supporting a Rejection Under 35 U.S.C. 103," PLI Practicing Law Institute How to Write Pat. Application App. C 2144 Appendix C (2001) ("particular parameter must first be recognized as a result-effective variable, i.e., a variable which achieves a recognized result, before the determination of the optimum or workable ranges of said variable might be characterized as routine experimentation").[2] See also, M.P.E.P. §2144.05 (recognizing the limited applicability of *In re Aller*, to cases involving the "optimization of ranges," and even then, the optimization must be of a variable that is recognized in the teaching of the art to be a "result-effective variable."[3]

Applicant submits that not only does the art not suggest which components of the alloy should be modified for result effective optimization, but also does not suggest that only the anode be so modified.

With respect to claims 5-7, the above argument is even more persuasive since the claims recite one alloy composition for the anode and a different one for the cathode. The art, again, does not suggest what alloy component is the result effective variable for

[2] Id., *citing*, *In re Antonie*, 559 F.2d 618, 195 U.S.P.Q. 6 (C.C.P.A. 1977) (claimed wastewater treatment tank volume to contractor area ratio was not recognized in the art to be a factor upon which treatment system capacity could be optimized and was, therefore not a result-effective variable.) and *In re Boesch*, 617 F.2d 272, 205 USPQ 215 (CCPA 1980) (prior art did suggest the balancing of a certain proportion as result effective).

[3] M.P.E.P. §2144.05 (the variable is one which is recognized to achieve a recognized result "before the optimum or workable ranges of said variable might be characterized as routine experimentation.")

optimization, and further does not suggest performing differing modifications on the anode and on the cathode. In addition, this is not even a case of *prima facie* obviousness in the selection of a claimed range where the prior art range is overlapping. *See*, Patent Law Fundamentals, Second Edition Mills III, et al. Eds, "The Substantive Requisites of a Valid Patent Chapter 10. Nonobviousness § 10:14 (2003) ("prima facie obviousness has also been held established in instances in which the only physical difference between what was claimed and prior art was numerical. Examples include ... cases where an overlap existed between the claimed range of numerical values and prior art numerical values).[4] And even if the ranges in the art and in the claim do not need to be overlapping or touching, they at least need to be close enough for the art to consider the teachings close enough to show the particular range that is suggested for optimization. See, *Gentiluomo v. Brunswick Bowling & Billiards Corp.*, 36 Fed. Apex 433, 438 (Fed. Cir. 2002) (unreported opinion stating the ranges need not overlap) and *Ex Parte Brunsveld*, 2001 WL 1057401 (Bd.Pat.App & Interf. 2001) (upper limit of about 12% in the reference and lower limit of about 15% in the claim were close enough that "*prima facie* one skilled in the art would have expected the compositions to have the same or similar properties."

This simply cannot be said about Baumler's disclosure of "trace amounts of other elements, such as zinc or manganese," (Col. 2, line 46) and the claimed 25% zinc. Further as noted above, Baumler neither teaches nor suggests anything approaching the claimed different compositions for the anode and cathode.

The same arguments apply to claims 8-11 and in addition as to claims 8-11 the argument of the Examiner still does not reach the level of a *prima facie* case of obviousness for the reason that Baumler does not even mention lead. Thus in addition to the lack of *prima facie* obviousness from the prior art teaching similar alloy

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[4] Id., *citing, In re Malagari*, 499 F.2d 1297, 1302-03, 182 U.S.P.Q. (BNA) 549, 553 (C.C.P.A. 1974); *In re Ornitz*, 53 C.C.P.A. 716, 351 F.2d 1013, 1017, 147 U.S.P.Q. (BNA) 283, 286 (1965); *In re Nehrenberg*, 47 C.C.P.A. 1159, 280 F.2d 161, 164, 126 U.S.P.Q. (BNA) 383, 385 (1960). *See also, Ex Parte Gibson*, 1998 WL 1766677 (Bd.Pat.App & Interf. 1998) (it is known in the art to provide a blade with as few as one and as many as 10 turns and to vary the length of the spike, clearly establishing that the particular number of turns and the length of the spike are result effective variables which are recognized in the art. This being the case, the selection of an optimum value for such variables is ordinarily an obvious matter which is within the skill of the art." citing, *In re Geisler*, 116 F.3d 1465, 1469, 43 U.S.P.Q. 2d 1362, 1365 (Fed. Cir. 1997), and In re Boesch, 617 F.2d 272, 276, 205 USPQ 215, 219 (CCPA 1980).

compositions, but not what is to be optimized and not using differing compositions for the anode on the one hand and the cathode on the other, all of the claimed elements are not found in the art as to claims 8-11. For *prima facie* obviousness all of the claim limitations must be taught or suggested by the prior art.[5]

For the above stated reasons the Examiner's rejections of claims 1-11 are improper and applicant respectfully requests that the Examiner withdraw the rejections of claims 1-11 and allow claims 1-11.

New claims 18-22 have been added to, in the case of claim 18, recite the wherein clause formerly in claim 1 as amended, as a positive recitation as opposed to a wherein clause, to overcome the examiners objection to the form of the wherein clause, and in the case of claims 19 - 22 to include disclosed features of the invention not previously claimed at all in the case of claims 19 and 20 or not claimed in the apparatus claims in the case of claims 21 and 22.

Applicants' authorize the Commissioner to charge the total amount of $146.00; $110.00 for the one-month extension fee and $36.00 for the extra claims fee to our Deposit Account No. 03-4060. Applicants do not believe any other fees are due in connection with this submission, however, if any fees are required, the Commissioner is authorized to charge any fees, or to credit any overpayment to our Deposit Account No. 03-4060.

Respectfully submitted,

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October 20, 2003

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[5] M.P.E.P. §2143.03. See *In re Royka*, 490 F.2d 981, 180 U.S.P.Q. 580 (C.C.P.A. 1974); *In re Wilson*, 424 F.2d 1382, 1385, 165 U.S.P.Q. 494, 496 (C.C.P.A. 1970) (must consider all of the claim language).

Basic Ar/Kr Ion Laser Power Supply Considerations

http://repairfaq.cis.upenn.edu/sam/laseraps.htm#apsbcs1

Small air-cooled Ar/Kr ion tubes require an operating voltage of around 100 to 110 VDC at 3 to 10 AMPs and a starting voltage of about 8 to 10 kV (but almost no current). While these basic requirements are in some ways similar to those of a HeNe tube, the shear value of the current - measured in AMPs - means that providing a power supply that doesn't self destruct, destroy the laser tube, or fry you in the process, is much more of a non-trivial task.

Note: Most parameters here are given for argon ion tubes since these are most common. However, while physically interchangeable krypton and mixed gas ion tubes are very similar electrically, they will have slightly lower starting and operating voltages. This isn't a problem for starting, but the difference in operating voltage can be significant enough to cause some power supply compatibility problems such as excessive power dissipation in the regulator circuits. This should be kept in mind if substituting tube types. See the section: Comparison of Argon and Krypton Ion Tube Characteristics for a specific example.

- The typical discharge voltage is 100 to 110 VDC into very nearly a short circuit - very low ohms. Theoretically, it is not a negative resistance as with a HeNe tube, at least. However, a combination of factors can still result in runaway if the effective series (ballast) resistance of the system is too low.

  The source for the operating voltage is either a direct line-connected rectifier/filter 'front-end' or this followed by a high frequency inverter. (RF excitation is also possible but I don't know of any commercial examples of this approach.)

- Operating current must be controlled and variable (to adjust beam power) from around 3 A to 10 A (which is the usual maximum specified current though more may be used in some cases and for larger lasers). Feedback based on tube current and direct optical monitoring of the beam (light control) is a must for continuous unattended operation. This provides the lowest noise and maximizes tube life. Modulation of the beam power can also be provided via an external input.

A series linear or switchmode (buck) regulator may be used with the line connected supply. Some power supplies use a combination of a switchmode preregulator to drop the rectified filtered line voltage to a range where a linear regulator can run with reduced power dissipation and use fewer, lower cost pass-bank transistors. Inverters will use PWM control of their drive.

- The Ar/Kr ion tube uses a heated filament-cathode. This requires a separate 2.5 to 3 V supply at 15 to 25 AMPs. The cathode must be up to operating temperature (usually about a 30 second to 1 minute delay from power-on in PREHEAT mode) prior to initiating the discharge to prevent damage to the tube. Commercial power supplies provide this delay automatically.

  A simple low voltage power transformer with a centertapped secondary usually supplies the filament current. Fine adjustment of filament current can be done using a tapped primary or Variac. The use of AC is actually beneficial and helps to spread the heat from the discharge over the extent of the cathode (filament) by dithering the arc position.

  Note that although the plasma temperature is extremely high, this is only true in the actual bore - which may start several inches away from the filament. Thus, you really do want the filament powered prior to initiating the discharge and at all times while it is running. If the filament loses power for some reason and cools down, the voltage drop between the filament and the discharge will increase leading to much greater power dissipation and hot spots. Depending on the main DC power supply, the discharge may just go out without any harm but for some, this may not be the case and the regulator may keep trying to maintain the specified current as the tube voltage climbs. I don't know how many times you can get away with this and how quickly it will damage or kill a tube but would rather not find out!

- The starter (generally called an igniter in this case - sounds much more impressive, doesn't it?!), must be designed taking into consideration that the full discharge current must pass through any blocking diodes or series

inductor/transformer. Therefore, those whimpy parasitic multipliers used for HeNe tubes will not work!

A design discharging a capacitor into a high current high voltage pulse transformer is normally used.

- Finally, while not strictly a power requirement, these Ar/Kr ion tubes requires LOTS of cooling. The air-cooled type must have a HUGE fan passing air through the elaborate heat sink fins of the tube with all plenums and/or baffles in place. After all, it will be dissipating 1,000 W OR MORE at full power - about the same as a medium size space heater!
- And, most important: Safety, electrical, and thermal protection and interlocks MUST be provided for this sort of high power laser equipment. Circuit failure or carelessness can result in unfortunate consequences. Optical shutters, beam-on indicators, and all other CDRH required laser safety devices are also essential.

Note that what we are talking about are Ar/Kr ion tubes putting out up to a few hundred mW of beam power. These are not small by HeNe laser standards. The lowest power models are still about 12 inches (30 cm) long with a diameter (including all the cooling fins and other attached structure) of about 4 inches (10 cm).

Large frame Ar/Kr ion tubes can be over a meter in length and nearly everything about them is, well, much larger. :-) There are even 8 FOOT (2.5 m) long monster medical lasers that output 35 W or more and require over 600 V at 35 A to power the tube. Figure on a direct feed from a local electric utility substation for this kind of power! Ion lasers like these may also have axial permanent or electro-magnets surrounding the tube to concentrate the discharge and other 'stuff' that we will kind of ignore. ;-) They also require several gallons per minute from a tap or chilled water source to prevent a melt-down.

For these reasons, while the offer of a cheap or free large frame ion laser may sound tempting, consider the power and cooling requirements before dragging it home. It will likely end up as a coffee table support or high-tech sculpture if you don't have industrial strength three-phase power at your disposal! Cooling water may also be a problem. Nonetheless, most of the basic information on small air-cooled ion lasers DOES apply to their bigger brothers as well if the numbers are adjusted appropriately. And, the power supplies are quite similar. In fact, the same power supply can often be used for a wide variety of ion lasers by selecting the AC input and changing some jumpers.

Throughout this chapter, references will be made to several commercial Ar/Kr ion lasers systems. Two of the most common are:

- American Laser Corporation (Salt Lake City, Utah), Model 60X second sourced as the Omnichrome (now a division of the Melles Griot Laser Group, Carlsbad, CA) model 532 (designated the ALC-60X/Omni-532). The general features of this laser are described (with photos) in the chapter: Argon/Krypton Ion Lasers. This is a small air-cooled argon ion external mirror tube good for up to several hundred mW on all or selected lines (depending on specific model). This is the most common laser of this type and relatively widely - and increasingly available on the surplus market.

  A few oddball versions of the 60X (60XB and 60XC) are still manufactured but the 532 is an obsolete model. American and Omnichrome both make/made a few zillion variations on the same theme. All of them look similar and have common features. American still makes replacement tubes for the 60X but they do much higher power with newer generation technology. Call ALC and request a generic brochure if you are curious (or more than curious).

  Photos of Various Laser Systems, Power Supplies, and Components has detailed views of various argon/krypton ion lasers including examples of the 60 series from American Laser Corporation. However, note that the ALC power supply shown in the photos will drive the same laser heads, it is NOT the same implementation as the Omni-150R described in detail in the section: Omnichrome 150R Power Supply and 532 Laser Head (Omni-150R/532). They differ physically as well: The ALC (there are a variety of versions) is in an elongated goldish-aluminum ("Alodined") box (as in the photos) while the Omni is shorter and painted black.

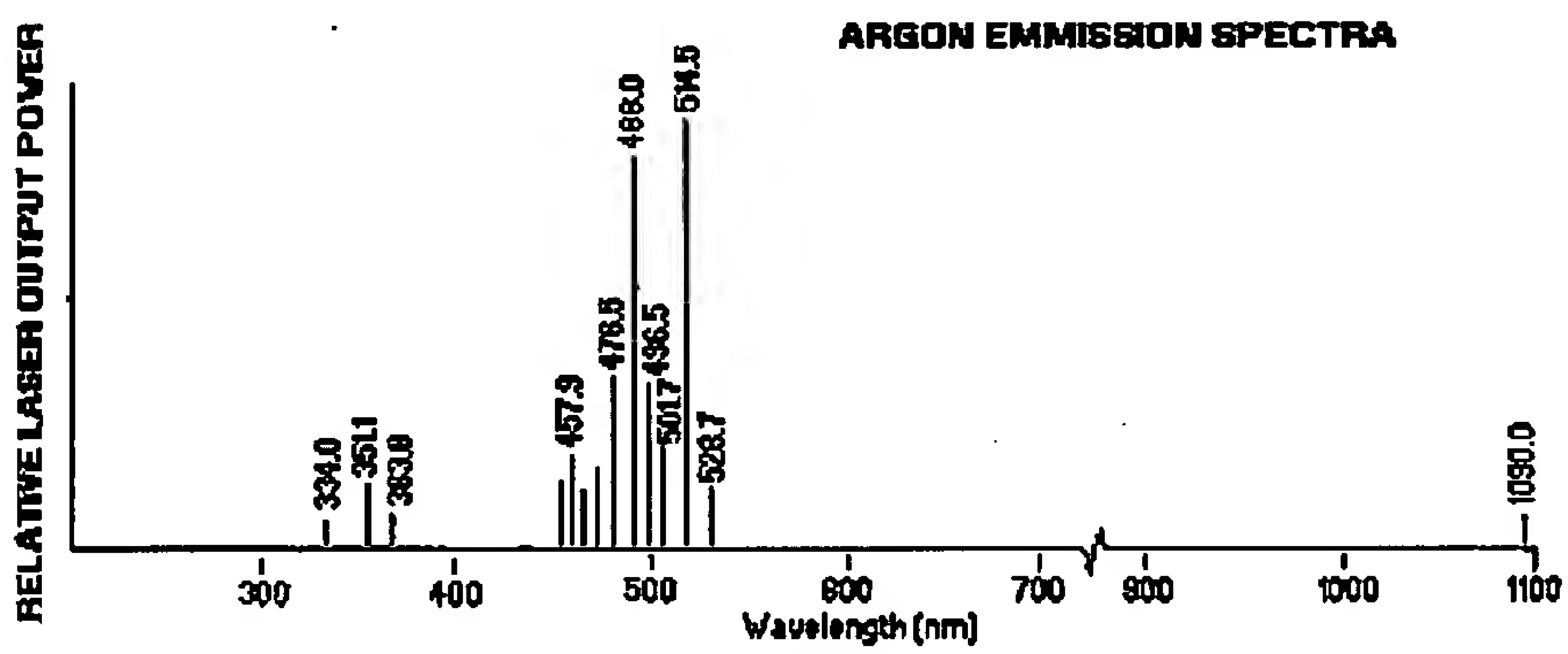
- Lexel Laser, Inc. (now out of business) Model 88 (designated the Lexel-88). They have various argon, krypton, and mixed gas ion lasers with up to several WATTS of beam power using the same linear power supply (though apparently not sold with the relatively small Model 88 anymore. This series is probably the next most commonly available ion laser compared to the ALC-60X/Omni-532.

Complete schematics of the power supplies and typical laser heads for these units are provided in the chapter: Complete Ar/Kr Ion Laser Power Supply Schematics.

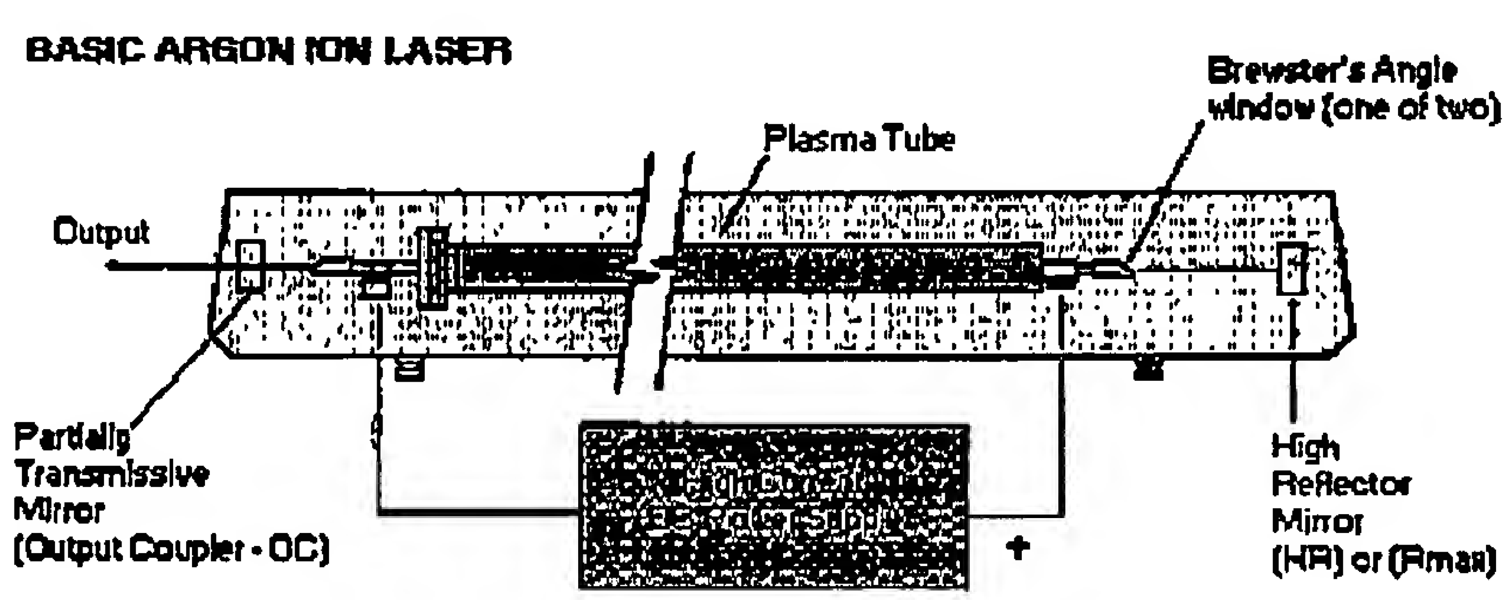
The Argon Gas Laser System

The Argon laser was invented in 1964 by William Bridges at Hughes Aircraft and is one of a family of Ion lasers that use a noble gas as the active medium. This laser is used in many applications such as:

- Forensic Medicine
- Entertainment
- General Surgery
- Ophthalmic Surgery
- Holography
- Optical "pumping" source



This image shows all the wavelengths of light emitted by the Argon laser operating in multi-mode. Every wavelength is a monochromatic light source of itself and each wavelength has a very narrow bandwidth. The two dominant wavelengths, of 514nm "Green" and 488nm "Blue" make up about 67% of the total beam output power. Single line operation is also possible by inserting prisms, diffraction gratings and other optical devices to "filter out" the unwanted wavelengths. Of course, when single line operation is required, the total output power decreases dramatically as well.



The laser resonator is made up of two mirrors. One is highly reflective (HR) and other is a partially reflective mirror (OC). From this optic (the Output Coupler) the beam emerges as laser light. The Brewster's Angle optic mounted at both ends of the tube, minimizes reflection loses

while creating a polarized beam. When the laser is first turned on, a delay allows for temperature stabilization. Then a pulse of high voltage (8 kilovolts DC) ionizes the argon gas. Upon ionization, high DC current (45 Amps) and about 600 volts DC across the tube maintains a sufficient discharge to keep the gas ionized. The typical Argon laser tube has a tungsten bore which has a high melting point and allows the laser to operate at higher power levels with longer tube life.

http://www.rli.com/resources/argon.asp